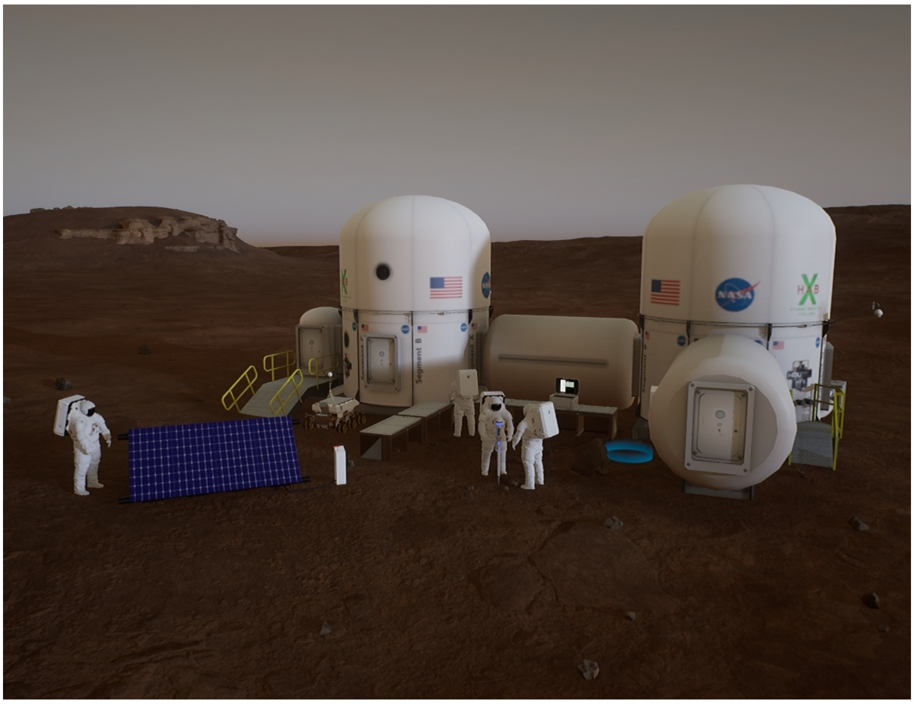
NASA MarsXR Challenge

Upgrades proposed for the martian
virtual training environment XOSS

Team: Overheat

Members:
Omar Gil Sturlese
Pol Sturlese Ruiz



Contents

1 Introducction

Space exploration has been an interest for humanity for a long time. So many missions have been completed, and there are yet many more to come.

For one of these missions, which will take place on the red planet, NASA, Buendea and Epic Games have initiated the second iteration of the NASA MarsXR challenge, and are requesting people to create new scenarios and assets for the new Mars XR Operations Support System (XOSS) environment, using Epic Games' Unreal Engine 5.

For the first part of the challenge, competitors are asked to design scenarios as storyboards. In our case, we have decided to also add this LaTeX documentation, to add some explanations to our ideas. The storyboards could be followed without having to read the full document, but it will give more detailed explanations about the idea of the storyboards and the different assets that are presented. It also has the reference to the information that we have used to justify our ideas.

Figure 1: Overheat's team logo

1.1 Assumptions

For our storyboards, we are assuming that there are some facilities already built and working (except if specified otherwise in a specific scenario):

- **Habitat:** A place with the necessary facilities where the astronauts will live.
- **Energy production system:** A system to produce electricity. We are assuming that there are at least solar panels. There might also be other sources of power.
- **Greenhouse:** A place for the astronauts to plant different crops.
- **CENTAUR rover:** A rover that can be used to transport materials and tools, or mount certain tools.
- **Drone:** A remote controlled drone with a camera and other systems.

2 Storyboard: Radiation testing

This storyboard is focused on testing the radiation underground.

Wen a colony is established on Mars, some buildings will be constructed underground (or at least for excavations). For that reason, it could be interesting to know how much radiation can the soil shield. If the radiation cannot fully penetrate the soil, underground buildings might be cheaper than expected in terms of materials, as the radiation protection might not need to be as intense as in the surface.

For this mission, we assume that the habitat's sensors have detected a radiation peak near the habitat. The astronauts need then to go near the place, mark a perimeter where the radiation is too strong for them to trespass safely, and then take some measurements of the radiation underground. They should take measurements from the safe zone, from the perimeter, and from the dangerous zone, being this last part obtained using the rover. Once they have the readings, they need to return to the base, examine how much radiation does the tools and the rover have, and change the radiation shields from the EVA suit.

During the mission, there could be some events that break the flow of the storyboard, and that the astronaut will need to deal with before completing the mission. Also, we have designed some metrics to assess in the correct execution of the scenario. Both things are explained in the following sections.

2.1 Metrics

For this mission, the metrics that we propose are the following ones:

- **Time:** The most basic metric that could be implemented is tracking the time that the astronauts take to complete the mission. It could be tracked in both ways: as a global time, and an individual time for each step. This way, scientists can measure which tasks are more complicated.
- **Radiation:** A metric for this scenario would be how much radiation does the tools, the rover and the suit have. Too much exposure to radiation can damage the objects, so it's better to minimize that value.
- **Number of readings performed:** The number of underground readings that the astronauts have performed
- **Drilling angle:** The angle that was used to drill the wholes. A vertical angle would be preferable, as it can then penetrate deeper in the Martian surface.
- **Length of the wholes:** The length of the wholes made could also be tracked, in case that a certain height for the wholes is wanted.
- **Tool's battery usage:** For the electrical tools that are used, if they are used with batteries, checking the amount of battery that has been used will help the astronauts make a better use of them.
- **Overheat:** This metric counts the time that a tool has been working without stopping. The idea is to track if the astronaut reaches a high level of overheat, which could damage the tool or the products that is being worked with.

2.2 Events

For this mission, the events that we have designed that break the flow of the storyboard are the following ones:

- **High radiation exposure:** If either the tools or the astronauts obtain a high measure of radiation, the astronauts will have to return to the habitat, as more exposure could be dangerous, and the mission will fail.

- **Malfunctioning tool:** The tool might stop working for different reasons, like having a broken part. The astronaut needs then to go back to the base and get a new one.
- **Tool's battery drained:** The battery of the tool has been completely drained. The astronauts need to grab a new battery and replace it before continuing with the task.
- **Tool overheat:** The tool has been used for too long without a pause, and it has stopped working. The astronaut needs to wait for the tool to cool down. (The event will be triggered when the overheat metric reaches the maximum).

2.3 Storyboard

Overheat, Radiation testing

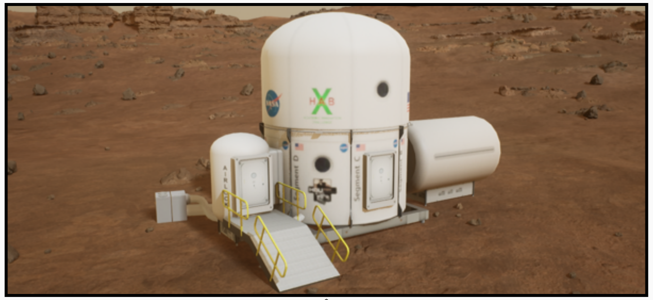
Storyboard Title, Sequence, & Description

1

Tool gathering

This scenario is focused on getting radiation information after a "radiation storm". The scaner has picked up a high level of radiation near the habitat, and the astronaut's mission is to examine the soil that has been affected, to determine how much radiation isulation does de soil provide. To do that, the astronauts need first to go to the shed and mount the deep core analysis drill into the CENTAUR rover.

5

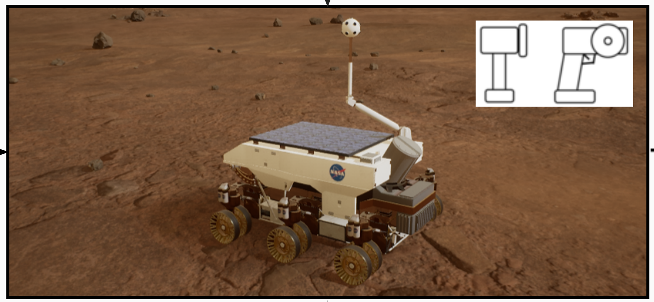


Assets Available in this Storyboard

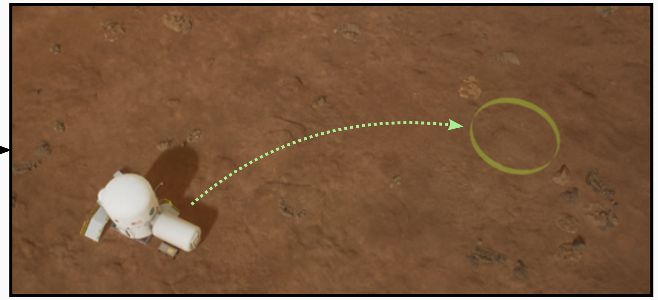
- CENTAUR Rover
- CENTAUR Remote Controller
- Toolbox

3

1



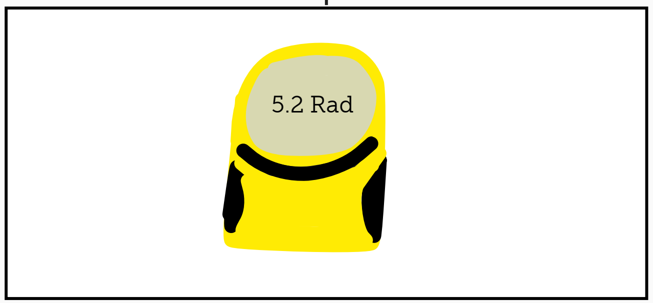
2



Actions Executable in this Storyboard

1. Grab the toolbox
2. Get CENTAUR's remote controller
3. Start CENTAUR and check that it boots correctly
4. Load the toolbox in the CENTAUR
5. Go to the radiation zone

4



Frame Descriptions

1 CENTAUR Rover + Remote Controller

2 CENTAUR Route

3 Toolbox

4 Geiger Counter

5 Mission Start Location - Main Base

Overheat, Radiation testing

Storyboard Title, Sequence, & Description

2

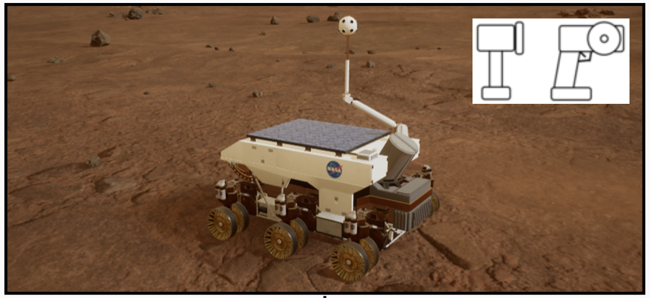
Perimeter delimiter

Once the radiated zona has been reached, the astronauts should mark a border to indicate where is the limit where the radiation is avobe safe levels. To do that, they should use the Geiger counter, and put some flags along the border.

Assets Available in this Storyboard

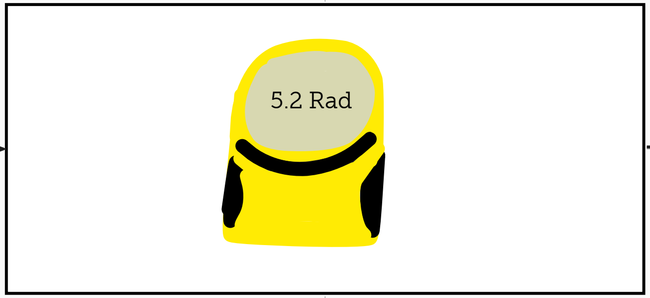
- CENTAUR rover
- Geiger counter
- Flag marker
- Camera

5

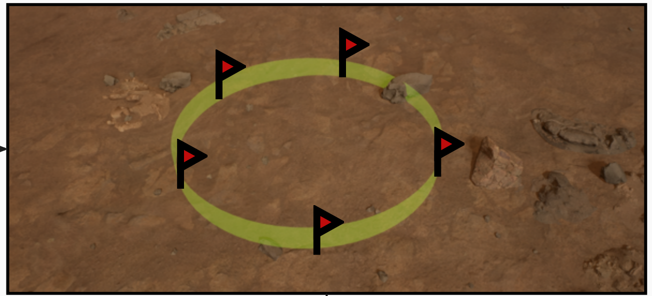


3

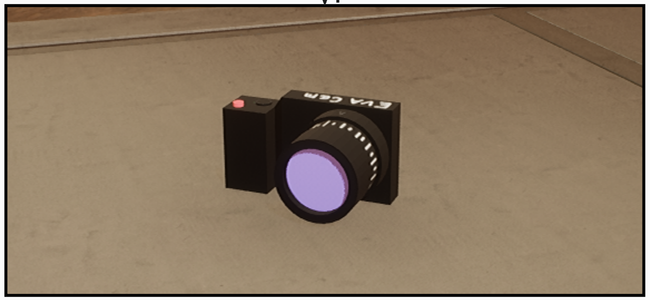
1



2



4



Actions Executable in this Storyboard

1. Open the toolbox
2. Get the Geiger Counter
3. Move along the radiated zone investigating with the Geiger counter. When the counter marks a high level of radiation, mark that part with a flag and don't cross it.
4. Once a border has been delimited, use the camera to take a picture of it.

Frame Descriptions

1 Geiger Counter

2 Area with Radiation

3 Toolbox

4 Camera

5 CENTAUR Rover + Remote Controller

Overheat, Radiation testing

Storyboard Title, Sequence, & Description

3

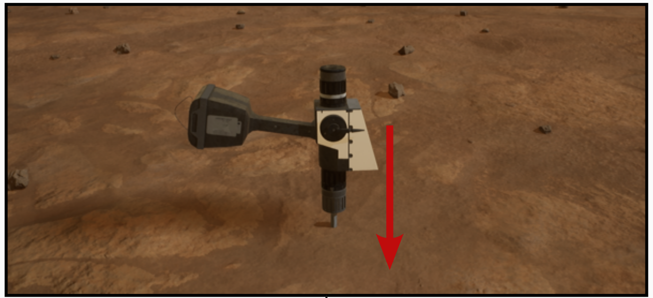
Safe zone mearuing

After delimiting the border, the astronauts should investigate the different zones, to see the radiation isulation level of the soil. They will start sampling the soil in the safe area, using the drill that is mounted on the CENTAUR, and getting reading of the radiation at different height levels.

Assets Available in this Storyboard

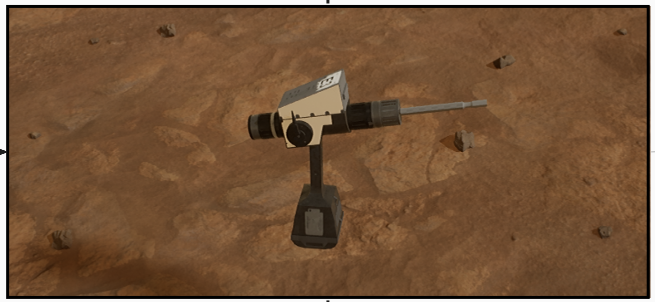
- CENTAUR Rover
- CENTAUR remote controller
- Deep core analysis drill
- Geiger counter

5

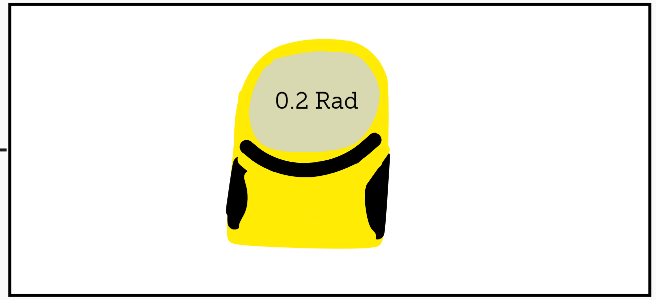


3

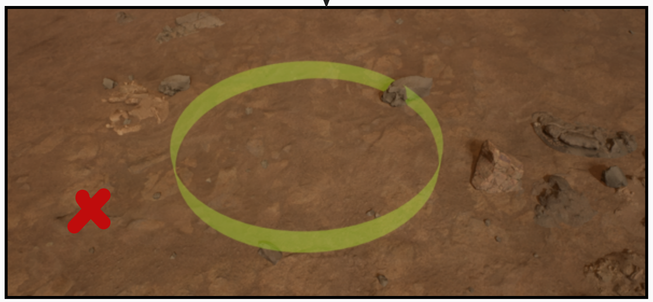
1



2



4



Actions Executable in this Storyboard

1. For each reading that is wanted:
    a. Using the Geiger counter, find a good spot to analyze (once scanned with the counter, the spots might appear in AR)
    b. Move the CENTAUR to the place found
    c. Operate the drill to get the radiation readings at different heights

Frame Descriptions

1 Deep Core Analysys Drill

2 Geiger Counter

3 Astronaut

4 Analysys Area

5 Subsoil Radiation Reading

Overheat, Radiation testing

Storyboard Title, Sequence, & Description

4

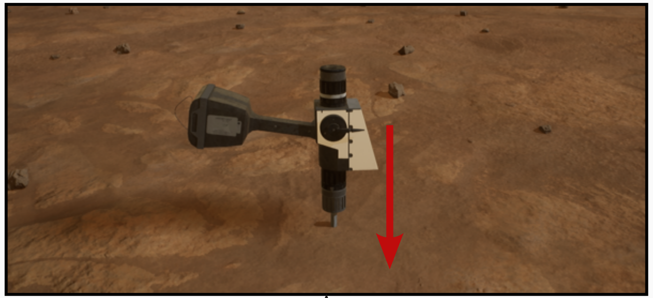
Perimeter sampling

Once the safe zone is investigated, the astronauts will take some readings of the safety perimeter. To do that, they will drill next to some flag markers and read the different values

Assets Available in this Storyboard

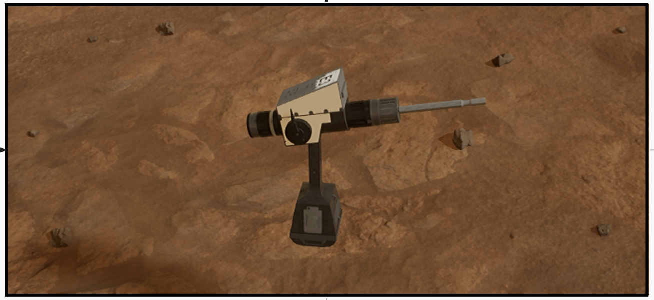
- CENTAUR rover
- CENTAUR remote controller
- Deep core analysis drill
- Geiger counter
- Flag marker

5

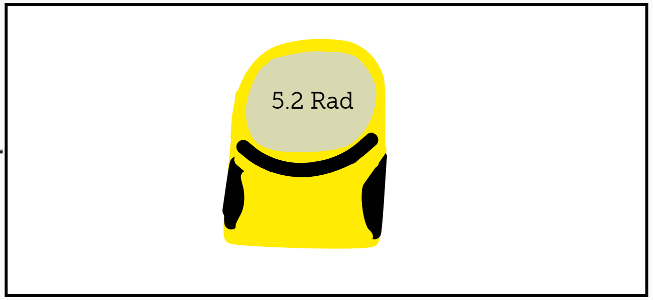


3

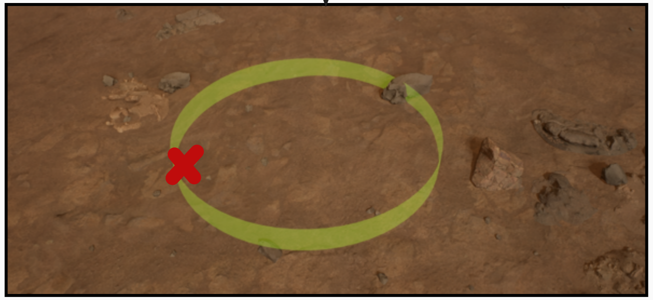
1



2



4



Actions Executable in this Storyboard

1. For each reading that will be taken:
   a. Move the CENTAUR near one of the flags that mark the perimeter
   b. Operate the drill to get the radiation readings at different heights

Frame Descriptions

1 Deep Core Analysys Drill

2 Geiger Counter

3 Astronaut

4 Analysys Area

5 Subsoil Radiation Reading

Overheat, Radiation testing

Storyboard Title, Sequence, & Description

5

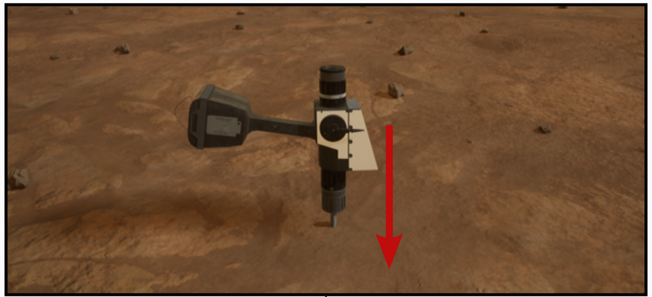
Danger zone sampling

The last part that will be sampled is the area insode the perimeter. Inside that zone, the levels of radiation are higher, and even though the suits could handle it for some time, it's safer to send the CENTAUR rover alone to do the sampling.

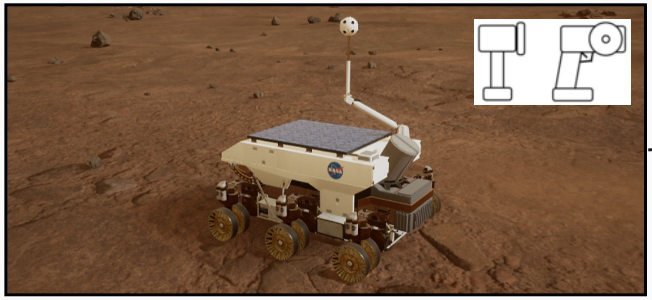
Assets Available in this Storyboard

- CENTAUR rover
- CENTAUR remote controller
- Deep core analysis drill
- Geiger counter (reader + display separated)

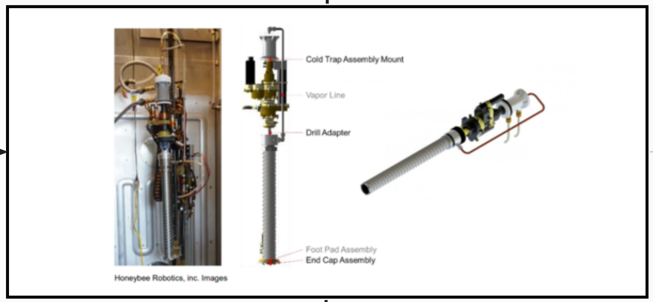
5



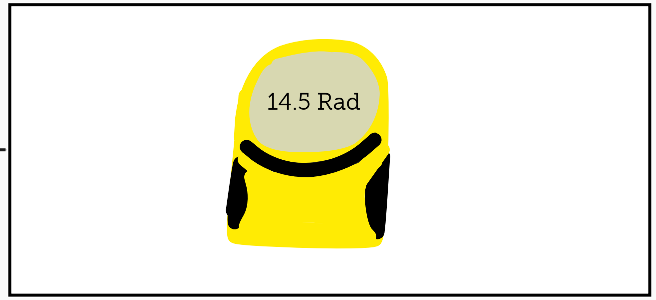
3



1



2



4

Actions Executable in this Storyboard

1. Get the Geiger counter and detatch the reader from the display
2. Install the reader on the rover
3. For each reading:
    a. Search for a good sampling spot moving the rover and using the Gieger counter display.
    b. Drill the soil using the remote command
4. Return the rover to the safe area
5. Uninstall the reader from the rover and attach it to the Geiger counter.
6. Store the Geiger counter back in the rover

Frame Descriptions

1 Deep Core Analysys Drill

2 Geiger Counter

3 CANTAUR Rover + Remote Controller

4 Analysys Area

5 Subsoil Radiation Reading

Overheat, Radiation testing

Storyboard Title, Sequence, & Description

6

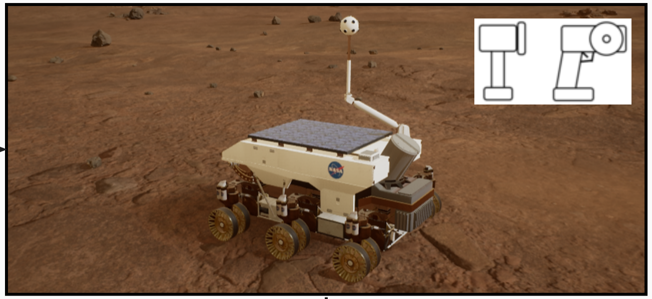
Cleaning and tool storage

Once al the readings have been done, it's time to return to the base. After being exposed to the intense readiation, it's needed to check the tools and the suit, and change the suit's radiation shield and any damaged parts in the tools and rover.

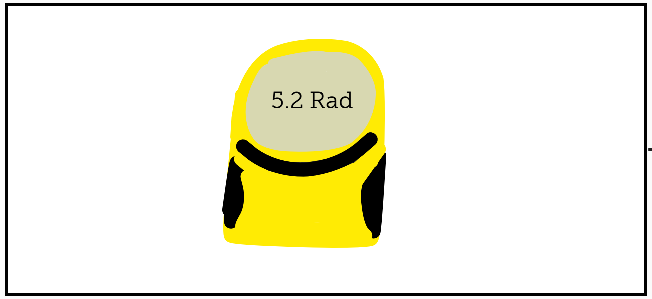
Assets Available in this Storyboard

- CENTAUR rover
- CENTAUR remote controller
- Deep core analysis drill
- Geiger counter (reader + display separated)
- Camera
- Flag markers
- Radiation shield renewer
- Spare parts from the CENTAUR and the drill

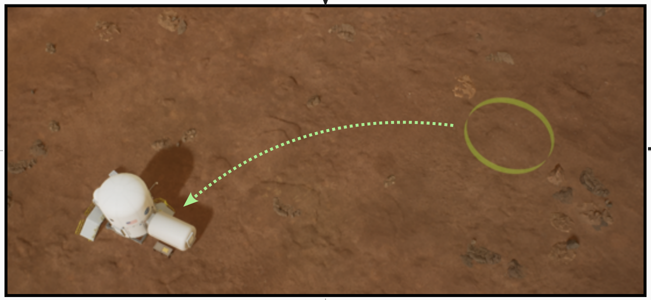
5



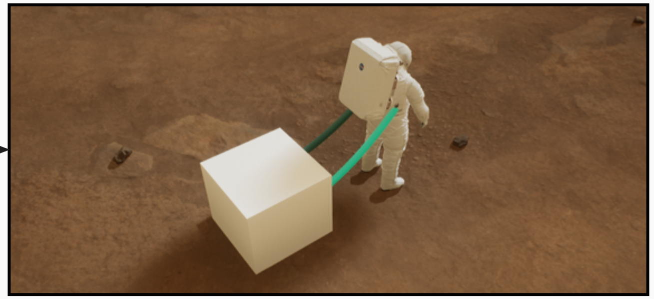
3



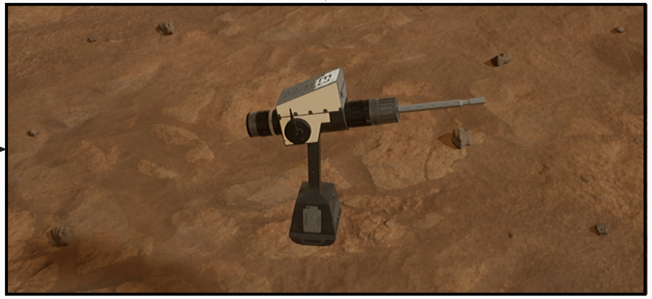
1



2



4



Actions Executable in this Storyboard

1. Go back to the base
2. Use the "radiation shield renewer" to change the liquid from the suit's radiation shield.
3. Go to the shed
4. Use the Geiger counter to detect if any part of the drill or the rover contains a high level of radiation.
5. Replace any parts with extreme radiation (ex: some panels from the rover)
6. Store the material in the shed
7. Park the rover in its spot and return the remote controller
8. Leave the shed and return to the habitat

Frame Descriptions

1 Return Route

2 Radiation Shield Renewer In Action

3 Geiger Counter

4 Deep Core Analysys Drill

5 CENTAUR Rover + Remote Controller

3 Props

In this section we describe a little further all the props that have been mentioned in the storyboards. Our goal is to include a little description of the prop that we have in mind, to make it more clear for the people who wants to develop our scenarios.

We also want to add some reasoning on why the asset would be useful, and what makes us think that it's possible to create it, so people can get a better understanding of the prop and their role in the different scenarios.

3.1 Toolbox

To maintain order during the mission, and avoid losing the tools, it will be necessary to have a toolbox. It might be needed different instances of this prop with different sizes, as not every tool might perfectly fit in a generic toolbox.

Figure 2: A model of a toolbox from the XOSS editor.

3.2 Screwdriver

A useful tool that might be needed in Mars is an electric screwdriver. The screwdriver should be able to perform the following operations:

- Screw
- Unscrew
- Change power applied
- Change the bit

The different bits that can be applied to the screwdriver are related with the screws that are used, and they are both described in section 3.3.

The screwdriver should also be stored together with the bits and screws in a toolbox like the one in section 3.1.

Figure 3: Early version of the screwdriver model.

NOTE: when in the storyboards we talk about the action of "screwing", we actually mean the whole process of choosing the right bit, get the correct screw, place it in the whole, choose the correct power and mode for the screwdriver, and screw the screw in place. The "unscrewing" action is analogous, but removing the screw and storing it.

3.3 Screws and screwdriver bits

For the screwdriver described in section 3.2 to work, it's needed to have some bits and some screws. To make it more realistic, there should exist different types of screws and their corresponding bits.

Also, for this iteration of the contest, it could be more engaging if the screws are not automatically set in place or they despawn after the use, but rather that the astronaut needs to manually put it in place or remove it and store it in the box.

Both the bits and the screws could be stored in the same toolbox as the screwdriver, to have an easy access to the entire tool set.

3.4 Gelger counter

This tool is used for used for measuring the radiation. The version that we envision is divided in 2 parts that are detachable: the radiation reader and the display.

We have designed the Gelger counter like this so it can be operated by a single person, but also that it allows to mount the reader on the CENTAUR rover, and remotely move them to analyze zones that are more dangerous for an astronaut, viewing the results in the display held by the astronaut.

3.5 Deep core analysis drill

This tool is a drill that can excavate a thin whole for some meters, and perform some measurements when it is underground. In our case, we have decided to measure the radiation level underground.

For the drill, we envision a tool similar to the ones proposed by Honeybee Robotics [1]: a drill that can excavate long distances underground, and that can take measurements from the places that it excavates.

Figure 4: Image from one of the Honeybee Robotics' drill.

The drill should be remotely controlled, so it can be mounted on the CENTAUR rover and operated from a safe distance. In figure 4 you can see an image from Honeybee Robotics' website, where thehy show a drill mounted on a rover.

3.6 Camera

This prop is already built in the XOSS editor. The idea is to use it to take pictures to document the missions and keep record of the places visited by the astronauts and the actions that they do.

Figure 5: A model of the camera from the XOSS editor.

3.7 Flag marker

This prop serves the purpose of marking specific points in a small area. It is not thought to be used to mark a place in the distance. For that, we have the waypoints that are already in the XOSS editor.

This flag could be use, for example, to mark certain features for future investigation, or to delimit a certain area.

3.8 CENTAUR rover

For martian missions it will be very helpful to have a rover accompanying the astronauts during the missions. It would also be very useful if the rover could carry some items around, because some material might be heavy or uncomfortable to carry. For that reason, we have designed a prop that it's a remote-controlled rover with some extra capabilities:

- **Carrying objects:** One of the main reasons for the use of the rover is to carry objects of big dimensions or to carry items for long walking distances.
- **Tool mounting points:** Another advantage of having a rover helping in the missions is that it can transport large tools and use them remotely using the controller. For that, the rover should have some places where the astronauts can attach specific tools that require some space to be operated. For example, if the astronauts are going to use a drill of great dimensions, instead of mounting it on every place, they could mount it on the rover, and move the rover from one place to another, which would save them time and energy.

The rover should also be divided in sections that can be disassembled, to be able to do some reparations in case they are needed. And also some interaction interface should be added to it, like a power button, a display or a connector socket (to connect it to other devices).

For this prop, we plan to use the CENTAUR rover that already exists in the XOSS editor, and modify it a bit to meet our ideas. For this reason, we have decided to keep it with the same name. In figure 6 you can see a version of the actual model from the XOSS editor divided by pieces and fully mounted.

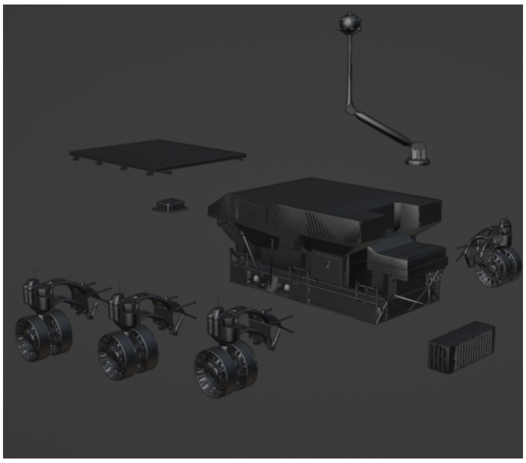
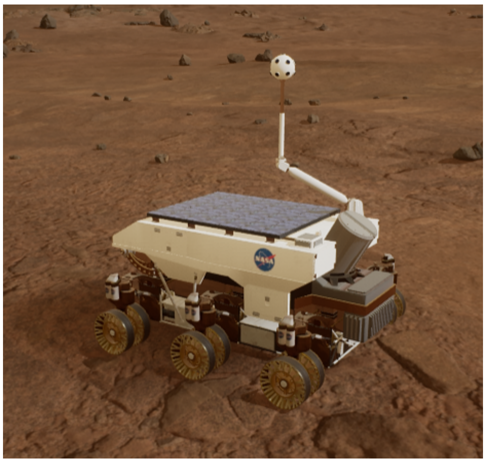
 

Figure 6: CENTAUR models. From left to right they are the model divided by parts and the model fully mounted and texturized in the XOSS editor.

The remote controller that will be used to move the CENTAUR rover is described in section 3.9.

3.9 CENTAUR controller

This prop is the remote controller of the CENTAUR rover (described in section 3.8). The idea is that it's able to control the rover's movement and other functionalities that it might have. In figure 7 you can see an sketch of the controller.

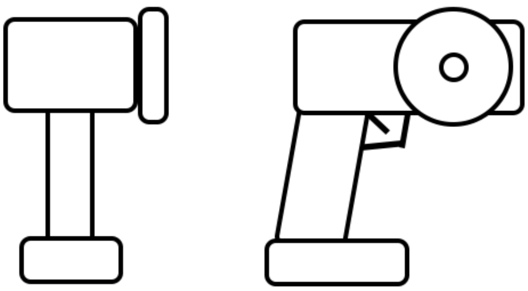


Figure 7: Sketch of the CENTAUR's controller. The image on the left is the rear view and the one on the right is the lateral view.

3.10 Radiation shield renewer

This prop that we have designed is thought to be in the outside of the habitat. The idea is that the EVA suit itself (the different layers of materials that compose it) protect the astronaut from radiation. However, as it is shown in [5], the suits can also have a layer of liquid circulating through the suit, which also acts as a radiation shield.

This prop we propose is used to change this liquid from the suit, so the radiated liquid can get out, and a new layer of clean liquid can be used to protect from radiation.

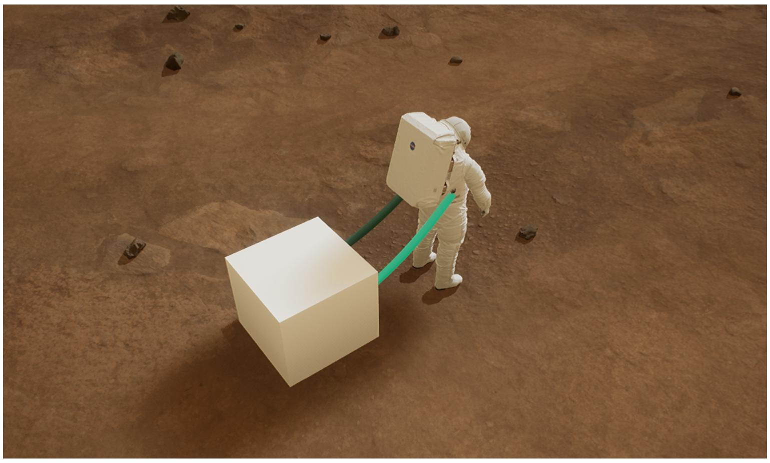


Figure 8: Mockup of the radiation shield renewer machine. In the picture, we can see an astronaut connected to the machine, renewing the liquid. The dark blue liquid is the dirty one (the one which has already protected the astronaut from the radiation) and the light blue one is the clean one.

4 References

[1] Drills. https://www.honeybeerobotics.com/products/drills/#1562267018150-cf7c081e-3ad71913-bc36.

[2] Exploration eva system concept of operations. https://www.nasa.gov/sites/default/files/atoms/files/eva-exp-0042_xeva_system_con_ops_rev_b_final_dtd_10192020_ref_doc.pdf.

[3] Exploration eva system concept of operations summary for artemis phase 1 lunar surface mission. https://www.nasa.gov/sites/default/files/atoms/files/topic_1-_eva_lunar_surface_concept_of_operations.pdf.

[4] Nasa 3d resources: 3d models. https://nasa3d.arc.nasa.gov/models.

[5] Space suit evolution from custom tailored to off-the-rack. https://sma.nasa.gov/SignificantIncidentsEVA2018/assets/space_suit_evolution.pdf.

[6] Neil Abcouwer, Shreyansh Daftry, Tyler del Sesto, Olivier Toupet, Masahiro Ono, Siddarth Venkatraman, Ravi Lanka, Jialin Song, and Yisong Yue. Machine learning based path planning for improved rover navigation. In *2021 IEEE Aerospace Conference (50100)*, pages 1–9, 2021.

[7] David L. Chandler. How to clean solar panels without water. https://news.mit.edu/2022/solar-panels-dust-magnets-0311, 2022.

[8] Andy Weir. *The Martian*. 2011.